

Coronagraph experiments with dynamic range absorption by pre-optics

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Abstract

We propose an extremely precise wavefront correction method for the direct detection of Earth-like planets at visible wavelengths. It consists of an intensity-Unbalanced Nulling Interferometer (UNI) together with Phase and Amplitude Correction (PAC) by two deformable mirrors. It works as pre-optics in front of any coronagraph in order to take full advantage of its performance. UNI-PAC can reduce the central star intensity and absorb a part of the dynamic range as a front optics, therefore a downstream coronagraph has only to achieve the rest of the total dynamic range. We show a preliminary results of the laboratory experiments to demonstrate the capability of UNI.

1. New Concept for very precise wavefront correction

For the direct detection of Earth-like planets, reducing speckle intensity below the planet level is a key issue as well as the suppressing diffracted light from parent star using a coronagraph. For this purpose, we have proposed UNI-PAC method to achieve extreme levels of wavefront control (Nishikawa et al. 2006). **The fundamental of this method is to magnify the wavefront errors by subtracting error-free wavefront with a nulling interferometer.** In the following, We briefly describe the principle of UNI. In this concept, we consider the complex amplitude $W(x, y)$ of a wavefront in a pupil plane (x, y) . It can be written as

$$W(x, y) = E_0 + \varepsilon(x, y)$$

where E_0 is the error-free complex amplitude, $\varepsilon(x, y)$ is the error component of the complex amplitude that is responsible for speckles in the image plane. Fig. 1 shows the schematic layout of UNI. It consists of an nulling interferometer, two deformable mirrors (DMs) and wavefront sensor. The two wavefronts are extracted from a single telescope, and the amplitude of the wavefront B is reduced by a factor of g and π phase shifted. Then two wavefronts are combined by a beamsplitter.

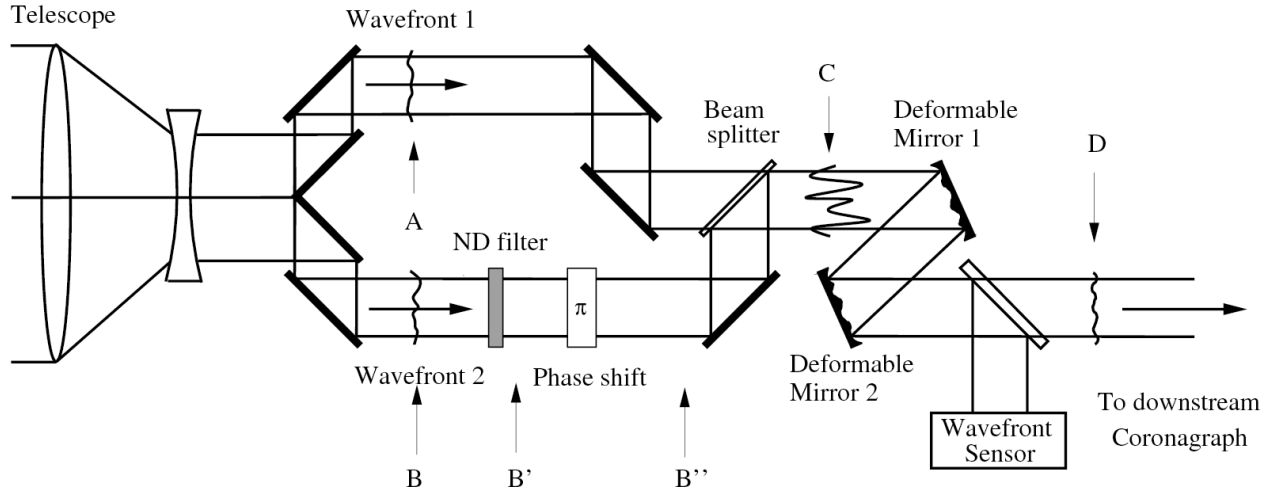


Figure 1: Illustration of UNI - PAC system.

The error-free wavefront is reduced by a destructive interference, however the error components remain at almost same levels as initial wavefronts. The intensity reducing of wavefront B is needed to avoid phase singularity in the pupil plane. The final error amplitude normalized by error-free wavefront is about 5 times magnified relative to the initial wavefront, if $g = 0.2$ is adopted. Fig. 2 illustrates these processes. The error wave magnification followed by two DMs will increase a sensitivity to correct very small wavefront errors. Moreover, UNI can reduce the central star intensity and absorb a part of the dynamic range as a front optics. Therefore a downstream coronagraph has only to achieve the rest of the total dynamic range.

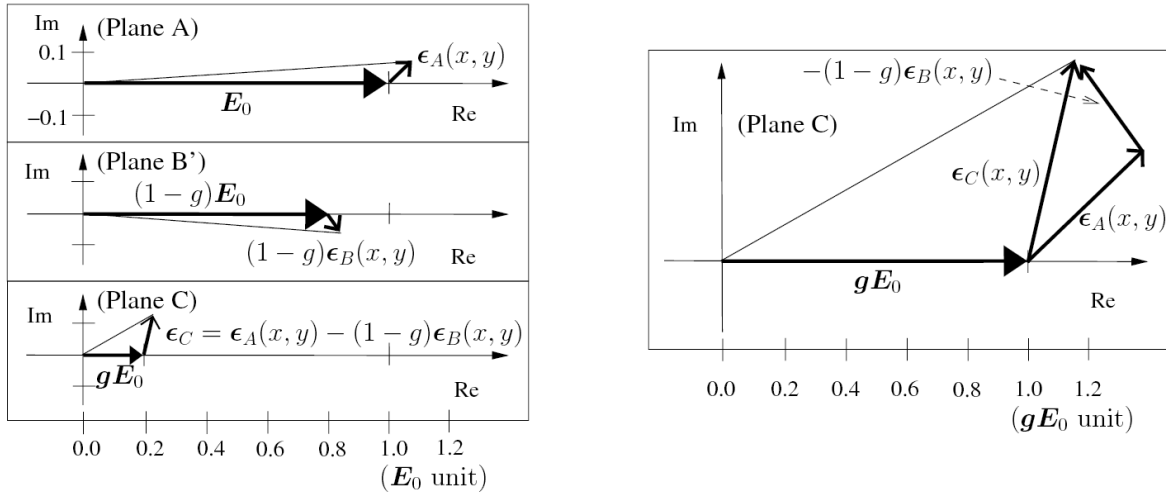


Figure 2: Complex amplitude of a point in the pupil plane.

2. Laboratory demonstration

We have constructed the laboratory testbed to demonstrate a capability of UNI-PAC for very precise wavefront correction (Fig. 3). In the experiments, two beams are generated by a beam splitter and they are combined under an intensity-unbalanced nulling condition. The half wave plates introduce π phase shift between two beams. The Shack-Hartmann wavefront sensor is used to measure the wavefront errors. Fig. 4 shows the measurements of the initial and magnified wavefront errors after UNI. We plan to use a 3-dimensional Sagnac common path nulling interferometer (Tavrov et al. 2005) as an achromatic nulloer or a downstream coronagraph.

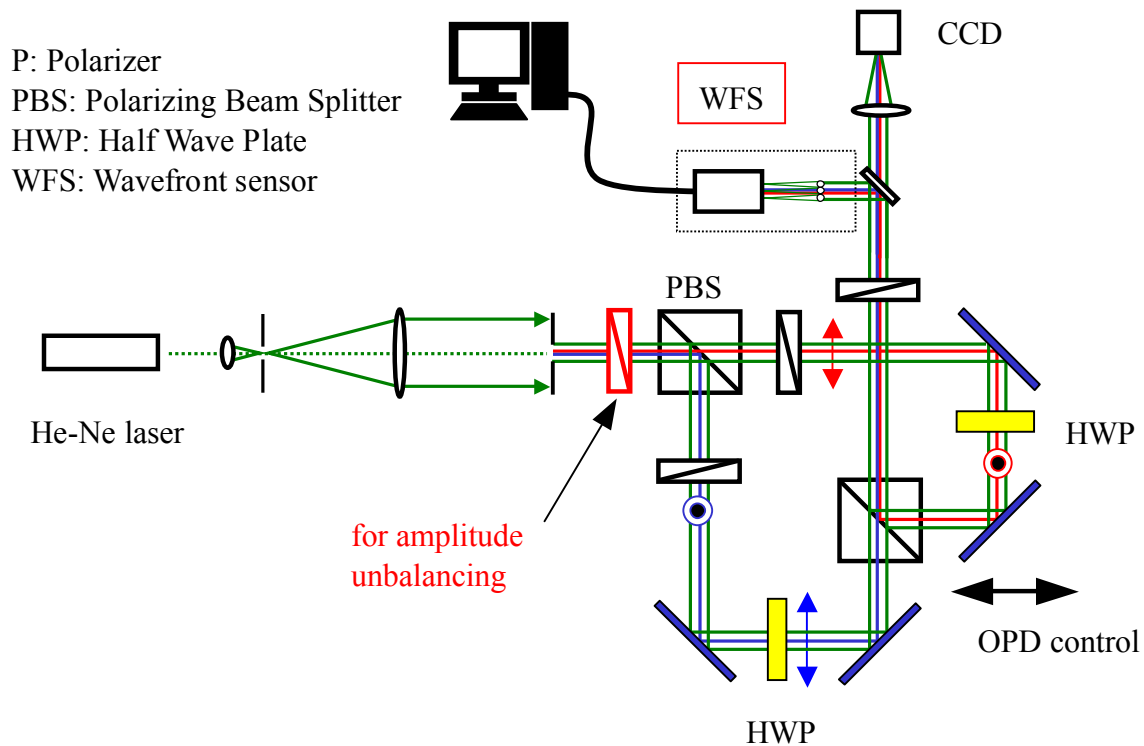


Figure 3: Unmatched Nulling Interferometer testbed.

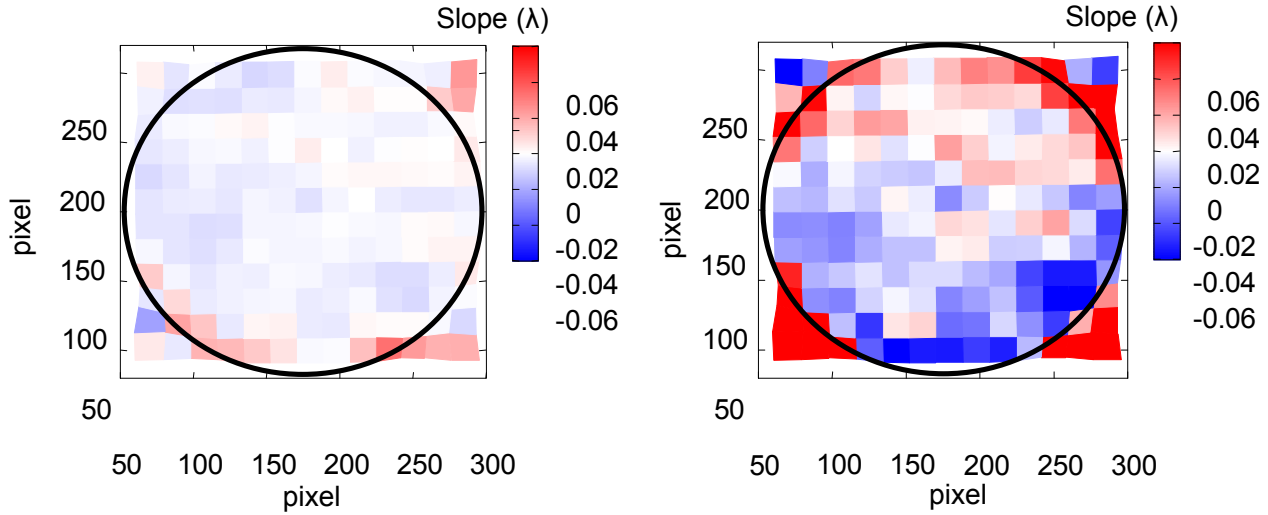


Figure 4: Left: Initial wavefront errors (Beam A) Right: Magnified wavefront errors

3. Conclusion

The UNI-PAC method will dramatically enhance a capability of a wavefront sensing and correction with a conventional AO system. Our laboratory experiments have demonstrated that the wavefront errors are successfully magnified with UNI, which is an important step towards very precise wavefront correction. The phase and amplitude error correction will be performed by two deformable mirrors in the near future. Detailed studies are also in progress by numerical simulations.

References

1. J. Nishikawa et al. 2006, A&A submitted
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